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## West Nile Virus and the Climate

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**ABSTRACT** *West Nile virus is transmitted by urban-dwelling mosquitoes to birds and other animals, with occasional “spillover” to humans. While the means by which West Nile virus was introduced into the Americas in 1999 remain unknown, the climatic conditions that amplify diseases that cycle among urban mosquitoes, birds, and humans are warm winters and spring droughts. This information can be useful in generating early warning systems and mobilizing timely and the most environmentally friendly public health interventions. The extreme weather conditions accompanying long-term climate change may also be contributing to the spread of West Nile virus in the United States and Europe.*

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Today, few scientists doubt that the earth and its atmosphere are warming. Most also agree that the rate of heating is accelerating, and that the consequences of this temperature change could become increasingly disruptive.<sup>1</sup> Some of the projected outcomes include ocean warming, rising sea levels and salt water inundation of settlements along low-lying coasts caused by melting glaciers, and weather patterns that are more erratic and storms that are more severe. Costs associated with climate extremes have risen exponentially since the 1980s, and the reinsurance industry estimates that these could rise to \$300 billion annually by 2050. Yet, less familiar effects could be equally detrimental. Notably, computer models project that global warming and the accompanying alteration in weather patterns will change the incidence and distribution of many infectious diseases.

### CLIMATE CHANGE AND HEALTH

Heating of the atmosphere and oceans can influence health through several routes. Most directly, it can generate more intense heat waves and greater mortality from heat stroke. Global warming can also threaten human well-being profoundly, if somewhat less directly, by revising weather patterns—particularly by increasing the frequency and intensity of floods and droughts and by causing rapid swings in the weather.<sup>2</sup> As the atmosphere has warmed over the past century, the hydrological cycle has been accelerated. Oceans are warming,<sup>3</sup> sea ice is melting,<sup>4,5</sup> and water vapor is rising.<sup>1</sup> Heat and droughts in arid areas have persisted longer, and bursts of heavy precipitation (>2 inches/day) have become more common. Aside from causing death by drowning or starvation, these disasters can promote the emergence, resurgence, and spread of infectious disease. Infectious illness may kill fewer

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people in one fell swoop than a raging flood or an extended drought, but once it takes root in a community, it often defies eradication and can invade other areas.

The increased climate variability accompanying warming will probably be more important than the rising heat itself in fueling unwelcome outbreaks of certain vector-borne illnesses. For instance, warm winters followed by hot, dry summers favor the transmission of infections that cycle among birds, urban mosquitoes, and humans, as happened in 1999 when the West Nile virus broke out for the first time in North America.<sup>6</sup> St. Louis encephalitis, a disease also involving *Culex* mosquitoes, birds, and humans, made its appearance in St. Louis in 1933 during the “dust bowl,” and most US urban outbreaks of St. Louis encephalitis have been associated with extended dry spells.<sup>7</sup>

The conditions underlying the outbreak of West Nile virus can be traced to global environmental change. While the precise means of introduction are not known, we have good evidence that the conditions that amplify the life cycle of the disease are mild winters coupled with prolonged droughts and heat waves—the long-term extreme weather phenomena associated with climate change. In addition, assessing the climatic conditions conducive to outbreaks of West Nile virus and using seasonal (e.g., 3-month) climatic forecasts may prove helpful for mobilizing timely and environmentally friendly public health interventions.

West Nile virus is transmitted by mosquitoes to birds and other animals, with occasional “spillover” to humans. What makes it different from many other mosquito-borne illnesses is that its primary carrier is an urban-dwelling mosquito, *Culex pipiens*. *Culex* typically breeds underground in the foul water standing in city drains and catch basins. During a drought, those pools become even richer in the rotting organic material that *Culex* needs to thrive; more rainfall would flush the drains and dilute the pools. Drought can also lead to a decline in the number of mosquito predators, such as frogs and dragonflies, and it may encourage birds to congregate around shrinking water sites, where the virus can circulate more easily. Meanwhile, high temperatures speed up the development of viruses within the mosquito carriers, which only live about 2 weeks (though very high temperatures are lethal to mosquitoes). The faster a virus develops, the greater the chance that it will reach a dangerous mature stage while the mosquito is alive and capable of biting. All of these factors enhance the possibility that infectious virus levels will build up in birds and mosquitoes living close to human beings.

In the spring and summer of 1999, all of these factors were present in the northeastern and mid-Atlantic states. In contrast, the unusually cool and wet weather in the spring and summer of 2000 may have reduced the threat of West Nile virus for humans, particularly when coupled with public health measures, including targeted spraying of pesticides and the application of chemicals and bacteria that kill mosquito larvae in storm drains.

Certainly, there are factors other than weather and climate that contribute to outbreaks of disease. Local environmental conditions can increase the potential for mosquito breeding in urban settings. Antiquated urban drainage systems leave more fetid pools in which mosquitoes breed, and stagnant rivers and streams do not adequately support healthy fish populations that consume mosquito larvae. But extreme weather contributed to the launching of West Nile virus in this hemisphere in 1999. Now, with the virus well established on America’s eastern seaboard, wide swings in weather—the projected hallmark of global climate change—threaten to encourage mosquito breeding and spawn new outbreaks in the future.

Weather extremes have played a significant role in the emergence and resur-

gence of dangerous diseases in the past. Hantavirus pulmonary syndrome—caused by a previously unknown virus related to one that killed US and UN soldiers during the Korean War—appeared suddenly in the southwestern United States in 1993. The disease is carried by rodents, and at the time of the appearance of the disease in the United States, populations of the *Peromyscus maniculatus* mouse had been boosted 10-fold by a sequence of extreme weather conditions—years of drought that helped reduce its predators, followed by heavy winter rains that encouraged the growth of the food sources of the mouse.

Since the mid-1970s, more than 30 diseases new to medicine have emerged.<sup>8</sup> Old infectious diseases are resurging, reappearing where they had been eliminated, or like West Nile, appearing where they have never been seen before. Contributing factors include deepening poverty in some areas, population movements, and medical and agricultural misuse of antibiotics; the damage is compounded by local and global environmental change.<sup>9</sup>

The appearance of a mosquito-borne illness in northeastern cities underscores just how global environmental change can directly affect our lives. In these days of international commerce and travel, an infectious disorder that appears in one part of the world can quickly become a problem continents away if the disease-causing agent, or pathogen, finds itself in a hospitable environment. Public and personal health is inextricably tied to a stable climate and to economic development and healthy ecosystems on continents far away, as well as at home.

## LEVELS OF SOLUTIONS

The health toll taken by global warming will depend to a large extent on the steps taken to prepare for the dangers. The ideal defensive strategy would have multiple components. One would include improved surveillance systems that would promptly spot the emergence or resurgence of infectious diseases or the vectors that carry them. Discovery could quickly trigger measures to control vector proliferation without harming the environment, to advise the public about self-protection, to provide vaccines (when available) for at-risk populations, and to deliver prompt treatments. However, comprehensive surveillance plans are not yet realistic in much of the world. And even when vaccines or effective treatments exist, many regions have no means of obtaining and distributing them.

A second component would focus on predicting when climatological and other environmental conditions could become conducive to disease outbreaks so that the risks could be minimized. If climate models indicate that drought is projected for a particular region along the East Coast avian flyway (Canada and across the Gulf of Mexico), such information could help “trigger” various levels of intervention:

1. Mosquito surveillance and active (live) surveillance of bird populations (including bleeding and testing birds, as opposed to passive surveillance or waiting until there are mortalities);
2. Cleaning of all storm drains and catch basins that might make relatively innocuous bacterial larvicides, like *Bacillus sphaericus*, more effective;
3. Organized cleanup of all potential mosquito breeding sites, like unused swimming pools and tires;
4. Early and consistent applications of larvicides; and
5. Targeted adulticiding when deemed necessary.

Internationally, officials might stock shelters with extra supplies if heavy rains and floods are projected for a given region. If satellite images and sampling of coastal waters indicate that algal blooms, sometimes related to cholera outbreaks, are beginning, officials could warn people to filter contaminated water and advise medical facilities to arrange for additional staff, beds, and treatment supplies.

A third component of the strategy would address global warming itself. Human activities that contribute to the heating or that exacerbate its effects must be limited. Little doubt remains that, by spewing carbon dioxide and other heat-absorbing (or “greenhouse”) gases into the air, burning fossil fuels for energy is playing a significant role in global warming.<sup>1</sup> Cleaner energy sources must be put to use quickly and broadly, both in the energy-guzzling industrial world and in developing nations, which cannot be expected to cut back on their energy use. In parallel, forests and wetlands need to be restored to absorb carbon dioxide and floodwaters and to filter contaminants before they reach water supplies.

## CONCLUSION

Climate, ecological systems, and society can all restabilize after stress, but only if they are not exposed to prolonged challenges or to one disruption after another. The Intergovernmental Panel on Climate Change, established by the United Nations, calculates that halting the ongoing rise in atmospheric concentrations of greenhouse gases will require a 60% to 70% reduction in emissions.<sup>10</sup> Climate does not necessarily change gradually.

The multiple factors that are now destabilizing the global climate system—greenhouse gas increases, loss of forests, and declines in stratospheric ozone—can together affect the stability of the global climate system and cause it to jump abruptly out of its current state. Amounts of change are one thing; the rates of change may be more important. Temperature changes are now occurring at 3°C per century; until 1999, they were 1°C per century. Moreover, the increased variability and wider swings between extremes now being observed in the system<sup>2</sup> may mean greater sensitivity and vulnerability to rapid change.

Just as we have underestimated the rate at which climate change is occurring, we have apparently underestimated the sensitivity of biological systems to small changes in average temperatures and the accompanying weather instability.<sup>1</sup> To protect our health and our well-being, restabilizing the climate system must become a chief priority for all sectors of society. Financial incentives, subsidies, and funds will be needed to redirect markets and shepherd the transition to energy conservation and clean energy technologies—a conversion that could provide the engine of growth for the global economy in this 21st century.

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